U.S. Department of Energy Smart Grid Investment Grant - Technical Advisory Group Guidance Document #4[*] -

Topic: Rate Design Treatments in Consumer Behavior Study Designs

August 30, 2010

TREATMENT: *In the context of Customer Behavior Studies, a treatment variable involves an influence offered or provided to a customer with the intent of altering electricity consumption behavior, and whose effect on behavior will be measured as part of a study or experiment.*

A key goal of the Department of Energy's (DOE) Smart Grid Investment Grant (SGIG) customer behavior studies is to provide experimental evidence that certain treatment variables are more or less effective in encouraging efficient consumption than other options, including the status quo. Ideally, the effect will be quantified in a way that leaves little doubt as to the cause and effect association, and that justifies extending the findings to similar treatments in other markets or customer situations. One of the main objectives for each SGIG Customer Behavior Study Plan is to outline and justify the treatment variables of interest. All of the consumer behavior studies incorporate treatments belonging to one or more of the following categories: recruitment strategy, rate design, customer education, in-home displays, and control or automation technology.

The purpose of this guidance document is to discuss the choices and issues associated with ***rate design*** treatments, including their relative research priority. Low priority rate designs include rate structures that have been used for years, whose implications are already well understood over most market circumstances, or that don't require smart grid technologies to implement. Higher priority designs include dynamic rates

[*] The following individuals on the Lawrence Berkeley National Laboratory Technical Advisory Group (TAG) drafted and/or provided input and comments on one or more of the U.S. Department of Energy Smart Grid Investment Grant (SGIG) Technical Advisory Group Guidance Documents: Peter Cappers, Andrew Satchwell and Charles Goldman (LBNL), Karen Herter (Herter Energy Research Solutions, Inc.), Roger Levy (Levy Associates), Theresa Flaim (Energy Resource Economics, LLC), Rich Scheer (Scheer Ventures, LLC), Lisa Schwartz (Regulatory Assistance Project), Richard Feinberg (Purdue University), Catherine Wolfram, Lucas Davis and Meredith Fowlie (University of California at Berkeley), Miriam Goldberg, Curt Puckett and Roger Wright (KEMA), Ahmad Faruqui, Sanem Sergici, and Ryan Hledik (Brattle Group), Michael Sullivan, Matt Mercurio, Michael Perry, Josh Bode, and Stephen George (Freeman, Sullivan & Company). In addition to the TAG members listed above, Bernie Neenan and Chris Holmes of the Electric Power Research Institute also provided comments.

with potentially high efficiency benefits, about which less is known and whose customer acceptance or impact (or both) could be enhanced if coupled with smart grid technologies.

As a first step, it is useful to distinguish between two electric product (or service) features. The first is whether the electric service is firm or interruptible. Most of the products being considered through the SGIG projects are for firm service, but interruptible service, such as direct and external control of premise devices under specified circumstances, could also be considered, and would have different design issues than those for firm service. The second product issue is whether the rate is meant to define the basic elements of a firm service (or default service in areas where retail choice is available) or whether it is designed as a product overlay that alters some aspect of the base design only under specified conditions, and is meant to apply for only a few hours per year, for example. This delineation is offered as a way to clarify the main differences among the core rate design choices, not as a hard and fast classification system. For example, time is a continuum and where we draw the line between "static" and "dynamic" rates is a judgment call. Similarly, distinguishing a rate structure as either a rate for basic firm service or a product overlay is something of a judgment call, especially when designs involve different combinations of features. Nevertheless, distilled to basics, there are really only about a handful of basic rate structures used for firm service today, a handful of product overlays, and a handful of choices related to frequency of price updates. Considering each of these separately makes the fundamental choices and issues clearer than it would be to try to parse through the 20-30 rate design combinations that can easily be formed from the underlying core design features.

RATE DESIGN FOR BASIC FIRM SERVICE

The conventional rate design process for regulated service typically begins with a determination of the total amount of revenue that is to be collected from a class of customers in order to cover the cost of providing service. If the goal is to design a rate for the residential class, the rate is designed to recover revenues that, in aggregate, will exactly equal the target revenue. For SGIG pilot rates, the target revenue could be based on a cost of service study, but is more likely to be based on the forecast of revenue for the class under the current rates for time period over which the rates are meant to apply.

The design parameters include the ***billing determinants*** which are used to determine a customer's bill. They include a ***customer or access charge*** (a charge per customer), an ***energy charge*** (per kWh) and, for larger classes, a ***demand charge*** (per kW) applied to the customer's maximum demand during some time period (which can be monthly or measured only during peak periods).

All of these billing determinants will then be designed to apply over some time period. Ignoring the customer or access charge which most rate structures include, typical rate structures include the following:

- Flat energy rates
- Flat demand/energy rates
- Tiered rates (inclining or declining blocks)
- Time of use rates
- Variable peak pricing rates
- Real time pricing rates

A flat rate applies to all usage over a specified extended period of time (e.g., 8760 hours in a year). Flat rates are typically the same over all hours of usage. Tiered rates vary by the level of energy usage in the billing period, which may be fixed blocks (inclining or declining) for the class or be customer-specific. Time of use rates typically apply to usage over broad blocks of hours (e.g., 6 hours for summer weekday afternoon vs. all other hours in the summer months). Real-time pricing rates generally apply to usage on an hourly basis. Variable peak pricing[1] is a hybrid of TOU and real-time pricing. The peak period is defined in advance, but the price established for the on-peak period varies by system or market conditions.

The final design dimension is how frequently changes in the relevant prices are posted. Flat, tiered and time-of-use rates generally stay the same at a minimum for 3-6 months, but often times are set for a year or longer at a time. Real-time rates fluctuate hourly, based on system or market conditions on a day-ahead, hour-ahead or real-time basis. Under variable peak pricing, off-peak prices are established to apply over longer periods of time, similar to TOU rates. The peak period is defined in advance, but the peak period price varies by system or market conditions that change daily. The timing of price changes can be combined with the different potential rate structures as shown in Table 1.

Design basis: Revenue neutrality.

Whatever the structure (and frequency of price updates), basic rates for regulated firm service are designed to recover the total revenue requirement assigned for each class, typically based on the average customer. When alternative rate structures with more dynamic features are designed, they must also be designed to be revenue-neutral to the class if the rate is going to be offered to the entire class.

Design Issues: Efficiency potential; windfall gains and losses; adverse selection.

The major benefit of designing more dynamic rates for basic service is that the potential for economic efficiency gains is the largest, simply because the rate would apply to all kWh sold, not just the kWh sold to a few customers who volunteer or just for a few hours during critical events.

However, going from a flat annual energy rate to a more time-differentiated rate that better reflects supply costs can have daunting customer impacts. If it is implemented on a mandatory basis, there will be windfall gains and windfall losses to customers due to the natural diversity in energy use patterns across customers. If they are implemented on a voluntary basis, they can lead to revenue erosion due to adverse selection: winners will tend to accept the rate, losers will tend to reject it, and the utility will lose revenue. This fear

[1] There is also a product overlay known as variable peak pricing which is a variant of critical peak pricing. In this document Variable Peak Pricing refers to a rate for basic firm service which is a hybrid of TOU and RTP.

of revenue erosion due to self selection is one reason why so many utilities who offer voluntary TOU rates to comply with the requirements of the Public Utility Regulatory Policies Acts (of 1978 and 2005) do little to market their availability.

Table 1. Typical Rate Structures for Basic Firm Service and Frequency of Price Changes

Rate Structure*	**Frequency of Price Changes****					
				Hourly Prices posted:		
	Annual	Seasonal	Monthly	Day-ahead	Hour-ahead	Real-time
All energy	✓	✓	✓	✓	✓	✓
Demand/energy	✓	✓	✓			
Tiered rates (inclining or declining blocks)	✓	✓				
Time of use (TOU) energy or demand/energy	✓	✓				
Variable Peak Pricing				✓	✓	✓
Real-time pricing				✓	✓	✓

*Most rate structures also include a customer or access charge, not shown here. -

**Table ignores fuel adjustment clauses which can also involve price surcharges that can be implemented - monthly or quarterly, usually on a lagged basis. -

Rate Design for Product Overlays

An alternative to redesigning the rate for basic firm service is to design a product that can simply overlay onto the existing firm rate under specified conditions, with no or only minor adjustments to the underlying firm rate. This design approach in effect creates a multi-layered rate that can capture some of the underlying supply cost dynamics. The basic rate is designed based on normal conditions. The overlays are invoked when certain system conditions occur (such as extremely high costs or system emergencies). Product overlays include:

- Interruptible/curtailable (I/C) rates
- Direct load control (DLC)
- Critical peak pricing (CPP)

- Peak time rebate (PTR)
- 2-part real time pricing (2-Part RTP)

Interruptible or curtailable (I/C) rates offer a credit or a discount if the customer agrees to be interrupted under given circumstances, for a given period of time, with specific notice requirements and penalties for non-performance.[2]

Direct load control (DLC) programs allow the utility to control certain energy consuming equipment to reduce loads during periods of high cost or system stress, thereby enforcing the curtailment obligation.

Under ***Critical Peak Pricing (CPP)***, prices change when utilities call critical events during pre-specified time periods (e.g., 3-6 PM summer weekday afternoons) based on short-term system conditions, high costs, or both. Under most CPP programs today, critical events are determined by system conditions, but the event price charged is known in advance and can be a single value or one of several levels.[3]

Peak Time Rebate (PTR) programs are very similar to CPP, except that:

- The participant is paid an event credit for energy reductions.
- The base rate + PTR rebate is not designed to be revenue-neutral.
- It requires a customer baseline load (CBL) to determine the amount of credit a customer gets paid.

For ***2-Part RTP***, a CBL must be determined, often based on the customer's prior year consumption. If the customer's load in the billing period is the same as the CBL, then the customer's bill will be identical to his bill on the basic firm rate. Deviations (up or down) from the CBL are priced at hourly marginal cost (or wholesale market prices), plus adders including risk premiums. This is a retail version of a contract for differences that is frequently used for wholesale transactions.

Design Basis: Value of Energy or Capacity Displaced ("load as resource")

For most product overlays, the price or credit is based on the administratively or market determined value of energy and/or capacity that it displaces, or on customer outage or shortage costs which other customers would otherwise incur. In this sense, load can be viewed as a resource, and its value is determined by the resources it would displace, not by historic or sunk costs that largely make up the revenue requirement for firm service.

---

[2] Most of the interruptible/curtailable rates that were offered by utilities in the past were designed for economic development purposes with interruptility as a secondary concern. For the purposes here, we are talking about a product overlay that is priced only to reflect the value to the system of load that can be interrupted under certain system conditions.

[3] There is a variant of CPP, also called variable peak pricing, in which in which the event price is not known in advance, but rather is determined by system conditions at the time the event is called.

Design Issues: Eliminates windfall gains and losses; efficiency potential is more limited.

The design issues for product overlays are the opposite of the design issues associated with basic service. The major advantage of product overlays is that there are no windfall gains and losses associated with redesigning the basic rate because the underlying firm rate doesn't change.

The biggest downside to product overlays (with the exception of 2-Part RTP) is that the economic efficiency potential is more limited than for rates for basic service because the number of hours in which the credit or price is in effect is far more limited. For example, if you have a CPP program in which 8 to 10 events per year are called, each lasting 3 hours, the total number of hours involved is 24-30 hours – less than one third of one percent of the hours in which electricity is consumed. Granted, those events should be times when electricity costs are extremely high, or system or local reliability would otherwise be compromised. Nevertheless, one third of 1% is a very small number of hours.

This intuitive logic is supported by at least one economic study of the two product design approaches. The benefits of variable peak pricing (a TOU rate where the on-peak price is set every day based on the day-ahead wholesale price of energy, plus adders) were compared to an ISO-administered demand response program which applied to far fewer hours per year. The results indicated that the VPP rate would lead to customer benefits ten times larger than the demand response program.[4]

Product-specific issues

With a ***CPP*** overlay, the rates for basic service are typically adjusted in order to maintain revenue neutrality for the class. That means that if customers are to be charged $0.80/kWh during all peak events, and the total amount revenue from that program would result in total revenues exceeding the target revenue, then the rate for the other 99.007% of the hours in the year will be reduced slightly to keep total revenues the same. Adjusting the basic firm rate to account for the revenue that result from the CPP avoids the need to establish a customer baseline load for billing purposes – all load within the critical event hours is simply charged the critical peak price. However, if the utility doesn't call all of the allowed events (due to mild weather, low market prices, or a recession, for example), the utility could experience a revenue shortfall.

PTR is not designed to be revenue neutral. The customer is billed for basic service according to her usage in the month. Then the PTR credit is calculated based on the customer's usage during the event compared to

---

[4] In testimony before the State of Connecticut Department of Public Utility Control, Henry Yoshimura compared the benefits of Connecticut Power & Light implementing a variable peak pricing rate for default service to the benefits of the ISO price-based demand response program. He concluded that ". . . retail customers would receive vastly greater benefits from price-responsive demand produced through retail rate design. . . . The results of this (ISO-sponsored) research estimated that the benefits of a default service or standard offer product indexed to day-ahead market prices, as applied to customers with 1 MW loads or greater, were greater than $340 million over a 5-year period. In comparison, an ISO-administered price-based program produced a benefit that was more than 10 times *less* over the same period – i.e., about $32 million." Henry Yoshimura, Pre-Filed Testimony of ISO New England Inc., Connecticut Light and Power Company Time-of-Use, Interruptible, Load Response, and Seasonal Rates, State of Connecticut, Department of Public Utility Control, Docket No. 05-10-03, February 10, 2006, p. 12.

the CBL. If the event load is higher than the CBL, there is no penalty. If it is instead lower, the customer receives a rebate equal to the credit per kWh times the kWh of load reduction. The main drawback is that PTR requires a complex and burdensome process to calculate the CBL, especially if the program is offered to mass-market customers, and especially if the CBL is defined according to the rules used for wholesale market programs which can entail tracking the hourly load for a number of business days preceding the event day (sometimes weather-adjusted), for example. Moreover, establishing a CBL only involves setting rules that are used for billing/settlement purposes. It does not resolve the basic evaluation question: what load reduction did the program *actually* produce? Although the evaluation issue applies to all rate design choices, especially when the change in design will require additional implementation costs (such as smart meters or control technologies), it is raised here to stress the point that defining rules for settlement purposes is not the same thing as determining the amount of load reduction that was achieved relative to what otherwise would have occurred. (More on the evaluation question in the next section.)

2-Part RTP maintains revenue neutrality at the customer level through the customer-specific CBL. It also offers greater energy efficiency potential than most rate structures because hourly prices are set every day (or day-ahead) for every day in the year. The main design issue is defining the customer-specific CBL. The ideal CBL would be what the customer's load otherwise would have been, which would require a forecast for the term of the RTP program. Historic loads are often used because they are perceived to be less subject to gaming than a load forecast, but the prior year might not be an accurate representation of the customer's expected CBL in the following year.

PRIORITIES FOR RESEARCH

Static vs. Dynamic Rates

Static rates like flat, tiered, and time of use rates that are only updated very infrequently (e.g., annually) are not a research priority in part because such rates have been around for a long time and are relatively well understood, and in part because they possess limited linkage to smart grid technologies. Even TOU rates can be implemented without smart meters.

Dynamic rates such VPP or RTP, or product overlays such as CPP and 2-Part RTP are of greater interest, especially when the project will address evaluation issues that are less well understood. Considering rate structure alone, dynamic rates for basic service are of the highest interest because they have not been widely adopted and thus much less is known about mass-market customer acceptance and response to these kinds of rate designs. Further, they apply to many more hours of energy consumption than product overlays, producing potentially greater benefits for both customers and utilities. However, they will also have the greatest customer bill impacts if customers are being transferred from a flat annual energy rate to a more dynamic structure, such as TOU-VPP (see Table 2). In the context of SGIG Customer Behavior Studies, peak-time rebate product overlays are of far less interest than other rate treatments due to the implementation problems identified above.

Among the dynamic rates, RTP and 2-Part RTP will provide the strongest price signal, but their total economic potential is more limited than a VPP rate simply because most customers will not be able or willing to manage their load against prices that change hourly. Their potential could be increased, perhaps greatly, with the use of enabling technology.

Table 2. Economic Potential of Different Rate Structures -

	Rate Structure	Economic Efficiency Potential	Bill Impacts Compared to Flat Annual Rates
Static	**Flat Rates, set annually**		
	• Flat Energy • Flat D/E • Tiered • TOU	• Lowest efficiency potential • Existing flat rates provide the baseline for comparing more dynamic rate structures	None (not applicable)
Dynamic	**Flat Rates (above) with a dynamic product overlay**		
	• Flat-CPP/PTR • Tiered-CPP/PTR • TOU-CPP/PTR	Moderate	Moderate/high
	Dynamic Base Rates		
	• TOU-VPP	High/very high	Very high
	• RTP	High/higher with enabling technology?	Very high
	• 2-Part RTP	High/higher with enabling technology?	Low

Need load and corollary data for all hours – not just event hours

Previous studies have observed that:

- *TOU rates (compared to flat rates)* resulted in daily peak load reductions of about 5%.
- *TOU rates combined with a CPP overlay (TOU-CPP) (compared to TOU rates alone)* have induced event reductions of about 20% compared to the TOU rate alone.[5]
- Adding control technologies to these rates can double or even triple event response.

---

[5] Ahmad Faruqui and Sanem Sergici. January 10, 2009. HOUSEHOLD RESPONSE TO DYNAMIC PRICING OF ELECTRICITY—A SURVEY OF THE EXPERIMENTAL EVIDENCE. Research was funded in part by the Edison Electric Institute and the Electric Power Research Institute. Questions can be directed to ahmad.faruqui@brattle.com.

The comparisons of event reductions across utilities and rate forms are very limited and don't tell us nearly enough about the economic potential of dynamic pricing. To determine a utility's peak load reduction (which would lead to capacity savings), complete hourly load data for all hours in the year would allow us to determine the utility's peak load with and without the dynamic rate. The hours in which the event occurred might or might not correspond to the utility's new peak. Even though load was reduced 20% in the event hours, the utility's new peak load (which might now occur in a non-event hour) might be only 2% lower, for example, because event conditions don't always coincide with the times of the actual system peak. Because all overlays except 2-Part RTP are limited to a few events per year, if the utility misses the peak hour entirely, there will be no capacity savings, even if the event load reduction is fairly high.

For these reasons the Department of Energy ". . . strongly urges all Project Teams to include in their evaluation plan the estimation of a fully-specified consumer demand model from which elasticity estimates can be derived." For projects that focus solely on estimating demand impacts from event-based dynamic prices, the project team will not be expected to report elasticity metrics, but will be expected to report other dynamic pricing metrics and customer demographic data that will allow other researchers to estimate consumer demand models.[6] Thus, it is important for each TAG to make sure that project proposals address plans for collecting and reporting the DOE-required data, even those data elements which may not be needed for the project's proposed evaluation. (This is a topic of another Guidance Document).

Use of incentives to encourage and maintain enrollment

There are many other design issues that can affect the quality of experimental results and our ability to measure and understand customer response to dynamic rates. One that is worth mentioning here is the use of incentives to encourage and maintain enrollment. On the one hand, customer incentives can play an important role in attracting and maintaining customers in a study on a dynamic rate. Without them, we run the risk that participation may fall so low that observed differences in the study aren't statistically significant.

But incentives can introduce their own distortions. For example, first-year bill guarantees, which have been used to increase voluntary participation, need to be considered very carefully in the context of a limited-duration experiment because by reducing bill risk, they may distort customers' true preferences for the given rate structure and potentially alter the marginal price of electricity thereby impacting the level of response.

[6] U.S. Department of Energy, "Guidebook for ARRA Smart Grid Program Metrics and Benefits," Washington, DC, December 7, 2009, p. D-2.